First Semi-Annual Report

(For Period January 1 - June 30, 1966)

on

NASA Multidisciplinary Research Grant

No. NGR-43-001-021

Submitted to

National Aeronautics and Space Administration

Washington, D. C.

by

University of Tennessee

Knoxville, Tennessee 37916

Carl O. Thomas
Associate Dean, Graduate School, and
Chairman, UT/NASA Committee

July 8, 1966

INTRODUCTION

This is the first semi-annual report on NASA Research Grant No. NGR-43-001-021 at The University of Tennessee, Knoxville, Tennessee. This grant, provided through the NASA Sustaining University Program, supports fifteen individual research projects in the physical sciences, the life sciences, mathematics, and engineering. It also supports a space sciences seminar.

The individual projects were solicited, screened, selected, and are generally administered by a faculty committee on the campus of The University of Tennessee. Sufficient flexibility is built into the program to allow the committee to make changes in the assignment of funds whenever this appears to be appropriate. Notification of such changes will, of course, be made to NASA as they occur.

The first fiscal year on this NASA Research Grant began January 1, 1966. Formal completion of the grant negotiations did not, however, occur until March 22, 1966. Most of the component projects did not get started until approximately April, 1966, and this is reflected in the detailed status reports.

GENERAL DISCUSSION

When formal notification of the grant was received in March, 1966, each of the principal investigators was asked to meet individually with the UT/NASA committee chairman for a detailed budget and program review. This was very near the end of the academic year, which affected the availability of graduate students. Consequently, the committee chairman authorized some minor redistribution of funds among the various projects. The redistribution did not affect the scientific content or program design of any of the projects.

Some of the projects were started in January, 1966. The investigators, and their department heads, understood that the availability of NASA funds from this grant for the early 1966 period would be contingent upon the effective date of the grant.

The small redistribution of funds, referred to earlier, allowed the UT/NASA committee to support the Mass Spectrometer purchase to a level of $20,000. Earlier budget estimates had indicated that approximately $17,000 would be available. The Chemistry Department, from its own funds, has added more than $21,000, and the remaining $5,000 has been obtained from grant funds provided by the DuPont Company. The concept of joint funding for a major item of equipment, using the NASA funds as a seed, appears to have been quite successful. We expect this instrument to be delivered and in use some time during the second report period.

Two additional project items have been added to the program locally. First, the UT/NASA committee chairman has assigned $500 to a discretionary fund account number. There have, in the past, been numerous occasions when small grants in the range of $50-$100 would have been extremely helpful to a research project. These have usually been needed for supplemental travel funds, special publications, or small, specialized items of equipment. The discretionary account will be used directly by the UT/NASA committee chairman for this purpose. No funds have been assigned to specific projects at this date.

Secondly, the committee has agreed to provide partial support for a Junior Science, Engineering, and Humanities Symposium which was conducted on the University campus in the spring of 1966. Approximately 100 carefully selected high school students from around the state and approximately 40 of their teachers attended this two-day symposium on the campus. Although the symposium was of broad scientific interest, a major element was oriented toward the space sciences and NASA activities specifically. One of the four major speakers was Otha Vaughn of the Marshall Space Flight Center, Huntsville, Alabama. The total funding for this symposium was as follows:

Army Research Office	$4,500
UT College of Liberal Arts	500
UT College of Engineering	500
Industrial Contributions	575

Approximately $1,200 more was needed to meet the actual cost of the symposium, and the UT/NASA committee has agreed to provide this amount.

An element of the initial proposal was the concept of generating alternative funding for the projects in order to release funds for new projects. The committee chairman is actively working with all of the investigators toward this goal. It is a little early to report much success, although Dr. Fletcher (Chemistry Department) and Dr. Deeds (Physics Department) have jointly received a $50,000 optical equipment grant from the Advanced Research Projects Agency, and Dr. Fletcher has received additional support from the Air Force. These funds do not completely replace the NASA support, although they are closely related and have allowed Dr. Fletcher to reduce his use of NASA funds by several thousand dollars. These efforts to generate alternate funds will continue during the next report period.

The local management responsibilities associated with this grant are providing some valuable experience. It is quite clear from recent public statements of a number of senior government officials that there is an increasing interest in supporting the "locally managed" research grant concept. The committee is consciously using the present grant as a vehicle for acquiring local management skill and insight into the associated problems. We have submitted a request for a supplement to this grant, and will be actively pursuing similar arrangements with the Department of Defense and other agencies as program support of this kind becomes available. The committee, and the University administration, feels that the locally managed multidisciplinary research grant program is a valuable means for meeting some of the special needs within the total University Research and Development program.

Some minor committee changes have been made. Dr. William S. Verplanck has resigned from the committee. Dr. H. M. B. Hurwitz (Psychology) and Dr. E. Gordon Ericksen (Sociology) have been added to the committee. The addition of Dr. Ericksen reflects a strong interest in expanding the program to include research within the social sciences. The supplemental application, which was submitted recently, contains a number of individual proposals from the social sciences.

Detailed progress statements on the individual research projects are included in the following section.

COMPONENT PROGRAM REPORTS

"Temperature-Induced Effects in Biological Systems"
Bruce M. Anderson
Department of Biochemistry

The major equipment for this project has been placed on order but as yet has not been received. The equipment ordered is as follows:

1 - Aminco-Bowman Spectrophotofluorimeter	$6,985
1 - Forma-Temp Jr. Refrigerated and Heated Circulator	$ 575

Arrangements have been made to assign Mr. James R. Heitz, graduate student, to this project as a research assistant. Research will begin on this project when the equipment has been installed and the necessary supplies obtained. Installation of the spectrophotofluorimeter should occur in late June.

"Mechanisms of Oxygen Metabolism"
Robert H. Feinberg
Department of Biochemistry

On May 1, a graduate research assistant, Paul Witkowsky, was assigned to this project. He is undergoing training at present. An oxygen electrode assembly ($200) has been ordered.

Progress to present only concerns such items as training of the student assistant and design of pressure equipment to be purchased.

"Alteration of Control Mechanisms--Effects on Cell Survival"
A. P. Levin
Department of Biochemistry

Preliminary studies, equipment selection, and personnel selection are now underway.

"Measurement of a Physiological Performance Index for the Man in Space"
J. F. Pierce and R. E. Bodenheimer
Department of Electrical Engineering

Work on this project was inititated at the beginning of the summer quarter, 1966. The first phase of this study consists of an intensive literature search. The objectives of this search are to determine the parameters that can be measured, the methods used to measure these parameters, the range over which the parameters can vary and the meaning of this variation. The literature search should be finished by November 1, 1966.

Three people are now active on this study. John Crouse, a doctoral student preparing for a dissertation, will be working full time during the summer quarter at no cost to the grant. As indicated on the budget, Pierce and Bodenheimer are working part time with appropriate charges to grant funds. No equipment has been ordered yet.

"Studies of Intermolecular Forces in Solution by Means of Isotope Effects: The Gas Chromatographic Method"
W. Alexander Van Hook
Department of Chemistry

All design work has been completed on the low temperature gas chromatograph which is to be used for the purpose of studying the effects of intermolecular forces in the liquid state on isotopic separation. Orders have been placed with various manufacturers and the components are presently being assembled into the final system. All shop work on the cryostat-temperature control-assembly is finished. Assembly should be completed within the next six weeks at which time testing will commence.

"A Mössbauer Type Investigation of the Long Range Conduction Electron Magnetization of Ferromagnetic Metals and Alloys"
J. O. Thomson
Department of Physics and Astronomy

I. The Program - The program to investigate the magnetic properties of CuNi alloys, and in particular the dependence of these properties on the state of order of the alloys, has proceeded since January 1966. In this study, the relative magnetization of the ^{57}Fe impurities in the CuNi alloys may be inferred from the hyperfine magnetic field felt by the ^{57}Fe which is determined using the Mössbauer Effect. From the observed hfs spectra obtained at different temperatures throughout the ferromagnetic region, one may determine whether there is a distribution of Fe magnetization and therefore if there are inhomogenities in the alloy magnetization. Such distributions may be influenced by prior heat treatment which result in differing states of order of the alloys. In addition, a better estimate of the Curie point may be obtained than from conventional magnetic measurements since the Mössbauer measurements can be made in zero field, and since the effects of inhomogenities and the state of order may be estimated. It is possible that relaxation time effects associated with the coupling of the electronic spins may be observed near the Curie point. Finally the magnetization of a magnetic impurity in a ferromagnet may vary with temperature somewhat differently from the magnetization of the host because of a difference between impurity and host in the strength of the coupling of the atomic moment to the host magnetization. This point is under investigation.

II. Progress to Date - CuNi alloys containing 30, 35, 40, 45 and 50 atomic per cent Cu have been prepared by arc melting the highly pure constituent metals in facilities kindly provided by the Metallurgy department. All but the 50% alloy have been homogenized by approximately one week of heat treatment near 1000°C in evacuated quartz capsules. ^{57}Co, the parent of the ^{57}Fe being studied, has been deposited on three of the samples, and diffused to a depth of approximately 10^{-3} cm by appropriate anneals near 800°C in evacuated quartz capsules.

Two complete hfs vs temperature runs have been made on the 30% alloy. A quenched alloy (cooled from 900°C to below red heat in approximately 10 seconds) showed rather broad hfs peaks near 80°K, but the Curie point, Tc, was quite well defined, Tc = 324±2°K. The same alloy with a furnace cool (~1 hour from 900°C to below red heat) showed somewhat broader hfs lines, and a substantially higher value of Tc of 335 ± 4°K.

The 40% Cu alloy has been run after a very slow cooling from 900°C (approximately 10°C/hour). The hfs peaks were considerably sharper than for the 30% alloy. A preliminary estimate of Tc for this alloy is 194 ± 5%. For the 50% Cu alloy Tc was found to be approximately 70°C.

At present two tentative conclusions can be drawn: a) The values of Tc for each of the alloys investigated are close to those reported in the literature for annealed alloys. b) If we extrapolate our hfs data to 0°K, using a $T^{3/2}$ law the value found for H_{eff} in each case lies somewhat below the value previously reported in the literature.

III. Additional Comments - Considerable time on the Mössbauer equipment is required to accumulate the data, and the equipment has been utilized almost continuously since January with less than half of the time available for this project. By July 1, 1966, the equipment should be almost completely available for the CuNi study.

An analogous experiment, not supported under this grant, is being carried out on NiAl alloys, and this experiment, of smaller scope, is nearing completion.

Thus far, no expenditures have been charged to NASA except for salaries.

"The Determination of Properties of Excited Nuclei and Related Solid State Information"
R. W. Lide
Department of Physics and Astronomy

Work started on this grant in January of 1966.

Robert W. Freeman has begun his Ph.D. research. He will do a perturbed angular correlation experiment on a radionuclide imbedded in a crystal. This work is expected to require two years. Mr. Freeman is still in the reading stage.

William O. Tucker obtained his Master's degree in June. He assembled and calibrated equipment for measuring the lifetimes of excited nuclear states. He tested the equipment by measuring the lifetime of the 14.4 kev excited state of ^{57}Fe. The equipment worked well but gave a lifetime for this state somewhat longer than previous measurements by other investigators. The difference was greater than that to be expected from experimental uncertainties. It is believed that the discrepancy was due to inadequate calibration equipment. Better calibration equipment has been ordered.* Neil Garrett will continue this work.

*Funds to buy equipment for this project are being supplied by the Physics Department.

Thomas D. Morris reactivated the angular correlation apparatus and produced a fortran program for having the data analyzed by the computing center. He tested the equipment and the program on the well-known angular correlation of ^{60}Co. The results were satisfactory. J. Keith Hiser will continue the angular correlation work.

Oak Ridge Technical Enterprises Corporation has loaned the Physics Department a lithium-drifted germanium detector. It is planned to make use of the high gamma-ray energy resolution of these detectors for decay scheme studies of radionuclides. A 4096 multichannel analyzer costing over $20,000 has been ordered for this work.* John Newcomer and Carl Pierce are setting various parts of this decay scheme apparatus into operation as Master's degree projects.

So far, the Nuclear Spectroscopy program has produced no published data. Up to now most of the effort has gone into setting up and testing the equipment on radionuclide with well-known properties. It is hoped to produce and publish original data within a year.

"Raman Spectroscopy: Development of Improved Sources and Spectrometer"
William H. Fletcher, Department of Chemistry
W. E. Deeds, Department of Physics

Work performed so far has been directed toward revision of the spectrometer design and the construction of a laser for use as a source of excitation. It was decided last December that the best design would be a double Ebert monochromator with two gratings turned by the same shaft. Calculations necessary for this revised design have been carried out with ray tracing computer programs.

Work on the use of radio frequency or microwave fields for excitation has received other support and therefore is not included in this report.

We have begun the construction of a gas laser (under this NASA program) for use in excitation of Raman spectra. We expect to use this with cells of our own design for producing Raman spectra in both liquids and gases.

"Application of Mass Spectrometry to Chemical Research at The University of Tennessee"
D. A. Shirley
Department of Chemistry

The concept of multiple funding on the mass spectrometer has been successful. NASA was requested to provide about 40% of the funds for this instrument. Of the total cost of $46,420 NASA funds provided 43%, a grant from the Dupont Company, 11%, and the remaining 46% came from the Chemistry Department equipment fund. The instrument has already been ordered, and we hope to have it in operation some time during the next report period.

*Funds to buy equipment for this project are being supplied by the Physics Department.

"An Experimental Investigation of the Stresses and Deflections of a Perforated Plate in Bending"
Charles W. Brown
Department of Mechanical and Aerospace Engineering

Since the inception of the project, work has been initiated in the following areas: Planning - A literature search was carried out to assess recent work in this area, as well as an evaluation of appropriate photo-stress equipment and a survey of prior work in the department and a study of its possible application to the present problem; Student and Staff Employment - Employment of a graduate student (Mr. D. C. Evans) to accept assignment in the fall; Work - We have obtained bids on photo-stress analysis equipment and renovated some equipment and test specimens used in prior investigations.

"Mixing of Flowing Gases"
Mancil W. Milligan
Department of Mechanical and Aerospace Engineering

Currently two graduate students are working on this project and will continue to do so in the future. I am spending approximately 1/4 time on the project and plan to continue this in the future. We have not purchased any new equipment to date.

Thus far we have fabricated an experimental facility and are in the process of refining our experimental techniques. We are also in the process of developing numerical schemes to solve the describing partial differential equations.

Our effort to date has been limited to a simple jet boundary configuration. As our experimental and analytical techniques are developed we will proceed to more complex configurations. Our results to date are encouraging and apparently we will be successful in advancing the technology in this area.

"Numerical Solution of the Non-Linear Partial Differential Equations of Viscous Fluid Motion"
Fred N. Peebles, Department of Engineering Mechanics
John H. Barrett, Department of Mathematics

The partial differential equations of viscous fluid motion (Navier-Stokes equations) provide a fundamental basis for analysis, design, and experimentation in many areas of aerospace engineering involving fluid mechanics. However, the analytical intractability of these equations is well known, and the inability of solving the equations of motion often results in undesirable and unreliable approaches to flow problems. Recent progress in the numerical solutions of these equations by finite difference methods at The University of Tennessee has pointed to new vistas of information and insight into viscous flow that can be gained through use of available computing equipment. The successful application of the numerical methods of solving the Navier-Stokes equations will permit accurate prediction of flow details in the entrance regions of nozzles, boundary layer development, and others that are technically important but not presently amendable to theoretical analysis. Objectives of the research are (1) to obtain additional

new solutions of the Navier-Stokes equations which involve further complications not yet experienced, and (2) to investigate the properties of solutions of the Navier-Stokes equations, and the criteria for unique and stable solutions.

New numerical solutions of the viscous flow equations were obtained for steady flow in a divergent channel for Reynolds numbers of 1, 10, and 1000. It was desired to assess the computational complications and computer-time requirements for a flow with non-regular boundaries. On the basis of the computer results and theoretical analysis, it was found that introduction of non-regular boundary points reduced the rate of convergence of the iterative computations employed, but that convergence was still possible with economically attractive computational times. Detailed verification of the numerical results were obtained for Reynolds numbers of 0.5 and 1.0. In general there was found agreement (within 5%) between the numerical and experimental measurements of strain rates at all points of the flow field. A paper based on this phase of the research is to be presented at the Fifth U. S. Congress On Applied Mechanics, June 14-17, 1966 at Minneapolis, Minnesota.

The next phase of the numerical studies will involve an investigation of transient flows to assess the possibilities for turbulent flow computations.

Dr. John H. Barrett and Dr. Julius Smith of the Mathematics Department have initiated research on properties of the Navier-Stokes solutions obtained by numerical means. Results of their first studies will be available by the end of 1966.

"Transport Coefficients for the Lennard-Jones (6,m) Gases"
H. W. Hsu
Department of Chemical and Metallurgical Engineering

Mr. Ronald Y. L. Koo, a second year chemical engineering graduate student, has been employed as a research assistant for the project.

The status on the project for the current period is summarized below: Experimental viscosity data have been compiled from the literature for most of noble gases and diatomic gases; a computer program to perform a numerical integration of the collision integrals for the Lennard-Jones (6,m) potentials is in preparation. However, the status of the program is not sufficiently progressed to announce the degree of completion; a modified Lennard-Jones potential is also under consideration to improve the physical model which will be adequate for both equilibrium and nonequilibrium properties.

For the next period it is anticipated to accomplish the following: Continuation of compilation work on experimental viscosity data from the literature; to smooth the compiled viscosity data for the determination of intermolecular potential constants; to keep working on the computer program for the calculation of the collision integrals.

"Study of the Sealing Mechanism and Surface Conditions in the Contact Type Shaft Seal for Critical Applications"
William K. Stair and A. J. Edmondson
Department of Mechanical and Aerospace Engineering

Current literature pertaining to the proposed area of study is being reviewed. Several papers have been found that seem to make a significant contribution to the proposed research. It is anticipated that the next few months will result in some definite conclusions regarding the feasibility of obtaining the objective set forth in the original proposal.

Mr. B. L. Sherrill will join the project in September, 1966, in an assistantship capacity. His background in industry ought to enable him to begin contributing to the project soon after his arrival.

"Macroscopic and Microscopic Criteria for Failure of Composite Engineering Materials"
A. Mathews, Department of Engineering Mechanics
E. E. Stansbury, Department of Chemical and Metallurgical Engineering

Mr. B. C. Sparks, an instructor in engineering mechanics, has been employed on a half time basis to work on the project. The Engineering Mechanics Department approved Mr. Sparks' Ph.D. thesis proposal which will be part of this project. The Engineering Mechanics Department, with the aid of the Graduate School and the College of Engineering, has purchased a new Instron testing machine which is essential to this project. Additional laboratory space has been obtained and is being readied for use for this project.

The objective of the current phase of the research has been the production of aligned tungsten wires in a Cu-Ag alloy matrix to produce a fiber reenforced composite on which mechanical property measurements may be made for correlation with theoretical predictions of the strength of such materials. The process presently considered is that of appropriately flowing a dispersion of metal powders and fibers in a liquid phase to produce semi-rigid rods, removal of the liquid phase, and final heating at a temperature at which a small amount of liquid metal phase provides a sintering mechanism resulting in a theoretically dense product.

Polystyrene dissolved in tetrahydronaphthalene and water solutions of Myrex (a hydrophilic colloid) have been investigated as dispersive liquids for mixtures of copper powder and wire segments (0.005" dia. x 0.4" long). Studies to determine flow conditions resulting in alignment of the wires have been restricted to extrusion through round dies. A high degree of alignment using the Myrex dispersion has been obtained but quantitative measurements of the distribution of fibers relative to the flow direction have not been made.

Mixtures of approximately 90% copper and 10% silver powder with polystyrene dissolved in tetrahydronaphthalene have been pressed for study of the removal of the latter by volatilization and thermal decomposition at low temperatures followed by sintering in hydrogen near 850°C. At this temperature copper and silver inter-diffuse resulting in an alloy containing about 10% silver-rich liquid phase which allows liquid-phase sintering mechanisms to operate to provide densification. Problems of gas evolution due to decomposition of the

organic material, carbon residues, and shape changes have been studied. Almost theoretical density has been obtained in several cases and the feasibility of this step in the production of fiber-aligned composites appears good.

Current research is being concentrated on the use of the Myrex solution as a dispersive medium for the powder-fiber mixture. Flow conditions for maximum alignment of fibers are under study. With respect to consolidation by sintering, the Myrex solution has the advantage that after removal of water the organic content of the product is less than 3%, substantially less than with polystyrene, and hence should produce less difficulty in sintering. Extensive sintering studies are planned for the next few months. From the standpoint of a high strength product, good bonding between the tungsten fibers and matrix is essential. In the present technique, this will require wetting of the tungsten fibers by the silver-rich liquid phase during sintering. Hence immediate research will be directed towards study of sintering rates in this system and the interaction between tungsten and the liquid phase.

"Space Science and Engineering Seminar"
Carl O. Thomas
Associate Dean of the Graduate School

The Space Sciences Seminar will begin in October, 1966. It is anticipated that the first seminar will be on the life sciences, and that two more seminars can be conducted in 1966. The series will continue through the end of the academic year in June, 1967.

A faculty committee has been partially organized to handle all program arrangements. We plan to design these seminars to focus upon the multidisciplinary aspects of the space sciences, but with some particular aspect as the key item each time. These seminars will be oreinted to the interests and needs of our own faculty and graduate students primarily. We will, however, enlist participation by the scientific community at large in this region, and we expect a good response from them. Program arrangements will be circulated widely in advance of each seminar.